The prevalence and causes of vision loss in Indigenous and non-Indigenous Australians: The National Eye Health Survey

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Abstract

Objective: To conduct a nationwide survey on the prevalence and causes of vision impairment and blindness in Indigenous and non-Indigenous Australians.

Design: Nationwide cross-sectional population-based field survey.

Participants: Indigenous Australians aged 40 years and older and non-Indigenous Australians aged 50 years and older randomly sampled from all levels of geographic remoteness in Australia.

Methods: Multistage random-cluster sampling was used to select 3098 non-Indigenous Australians and 1738 Indigenous Australians from 30 sites across five remoteness strata with a response rate of 71.5%. Sociodemographic and health data were collected using an interviewer-administered questionnaire. Trained examiners conducted standardised eye examinations, including visual acuity, perimetry, slit-lamp examination, intraocular pressure, and fundus photography. The prevalence and main causes of bilateral presenting vision loss (visual acuity worse than 6/12 in the better eye) were determined and risk factor analysis was conducted.

Main Outcome Measures: The prevalence and main causes of vision impairment and blindness.

Results: The overall prevalence of vision loss in Australia was 6.6% [95% confidence interval (CI): 5.4-7.8). The prevalence of vision loss was 11.2% (95% CI: 9.5-13.1) in Indigenous Australians and 6.5% (95% CI: 5.3-7.9) in non-Indigenous Australians. Vision loss was 2.8 times more prevalent in Indigenous Australians than non-Indigenous Australians after age and gender adjustment (17.7%, 95% CI: 14.5-21.0 vs 6.4%, 95% CI: 5.2-7.6, $p<0.001$). In non-Indigenous Australians, the leading causes of vision loss were uncorrected refractive error (61.3%), cataract (13.2%), and age-related macular degeneration (10.3%). In Indigenous Australians, the leading causes of vision loss were uncorrected refractive error

(60.8%), cataract (20.1%) and diabetic retinopathy (5.2%). In non-Indigenous Australians, increasing age [odds ratio (OR) 1.72 per decade, 95% CI: 1.40-2.10] and having not had an eye examination within the past year (OR 1.61, 95% CI: 1.06-2.42) were risk factors for vision loss. Risk factors in Indigenous Australians included older age (OR 1.61 per decade, 95% CI: 1.34-1.95), remoteness (OR 2.02, 95% CI: 1.23-3.31), gender (OR 0.60 for males, 95% CI: 0.42-0.84), and diabetes in combination with never having had an eye examination (OR 14.47, 95% CI: 5.65-37.05).

Conclusions: Vision loss is more prevalent in Indigenous Australians than in non-Indigenous Australians, highlighting that improvements in eye healthcare in Indigenous communities are required. The leading causes of vision loss were uncorrected refractive error and cataract, which are readily treatable. Other countries with Indigenous communities may benefit from conducting similar surveys of Indigenous and non-Indigenous populations.

Introduction

Globally, approximately 223 million people suffer from vision loss,[1] of which 80% of cases are avoidable through early detection, prevention and treatment.[2] The feasibility of reducing the burden of vision loss prompted the World Health Assembly (WHA) to endorse "Universal Eye Health: a Global Action Plan 2014-2019" (the Global Action Plan) in 2013, that aimed to reduce the prevalence of avoidable blindness by 25% before the year 2020.[3] The WHA emphasised the need for population-based survey data on the prevalence and causes of vision loss to inform resource allocation for eye healthcare services in order to achieve the objectives of the Global Action Plan.[3]

Fewer than 20% of countries have conducted nationwide surveys on the prevalence and causes of vision loss, and existing studies vary in terms of methodological rigor.[2] In this manuscript we contend that the methods used in most surveys to date are limited in their ability to provide a sufficiently detailed map of a nation's eye health, particularly in countries with disadvantaged Indigenous groups. The definition of indigeneity is contentious and varies considerably, however, the United Nations Permanent Forum on Indigenous Issues loosely defines Indigenous peoples based on the following criteria: 1) self-identification as Indigenous peoples by individuals and acceptance as such by their community; 2) historical continuity and land occupation before invasion and colonisation; 3) strong links to territories including land and water and related natural resources; 4) distinct social, economic, or political systems; 5) distinct language, culture, religion, ceremonies, and beliefs; 6) tendency to form non-dominant groups of society; 7) resolution to maintain and reproduce ancestral environments and systems as distinct peoples and communities; 8) tendency to manage their own affairs separate from centralised state authorities.[4] There are 370 million Indigenous people in 90 countries, and they consistently suffer from significantly poorer health outcomes than their non-Indigenous counterparts.[5, 6] This gap is particularly pronounced in developed

nations with historically colonised Indigenous minorities, including the United States of America, Canada, New Zealand and Australia, where Indigenous morbidity and mortality rates are higher than many developing nations.[7] Considering that vision loss is more prevalent in disadvantaged communities,[8] it follows that many Indigenous populations are likely to have a higher burden of vision loss. Nationwide studies have been conducted in regions of Asia, Africa and Europe with Indigenous populations, but none have attempted to collect samples from Indigenous groups.[9-22] By assuming ethnic homogeneity and neglecting to interrogate Indigenous communities, these surveys may have insufficiently quantified the burden of vision loss in some of their countries' most vulnerable groups. Consequently, they may have underestimated the prevalence of vision loss and generated data that is insufficient to optimally inform national interventions.

With the exception of two surveys conducted in Australia,[23, 24] all surveys investigating Indigenous eye health have been subnational and focused on isolated tribes or communities with varying degrees of sampling bias,[25-33] and most did not make robust comparisons with non-Indigenous groups[25, 27, 28, 30, 33] or collect comprehensive ophthalmic data.[29, 30] Nevertheless, the majority of these surveys, in conjunction with other research, have found that Indigenous communities in Brazil, Ecuador, USA and Australia have high rates of vision loss[24, 34, 35] and eye disease, including trachoma,[30, 36] cataract,[25] pterygium,[25, 37] and diabetic retinopathy.[24] Therefore, as Indigenous peoples constitute more than 5% of the global population, [7] identifying the prevalence and causes of vision loss in these groups in conjunction with general populations is critical to inform national eye health programs and to achieving the objectives of the Global Action Plan.

Australia requires national prevalence data on vision loss to fulfil its obligations as a signatory to the Global Action Plan. State-level surveys conducted in the early 1990s in Victoria,[38] New South Wales[39] and South Australia[40] have been the reference studies in

Australia until now. We conducted the first National Eye Health Survey (NEHS) to determine the prevalence and causes of vision loss in Australia. This is the first nationwide eye health survey conducted in any country that has stratified its sampling frame according to Indigenous status to produce reliable estimates of the prevalence and causes of vision loss in both Indigenous and non-Indigenous populations. Here we present the findings of the NEHS and we propose that our stratified study design forms the basis for future prevalence studies in all countries with Indigenous groups.

Materials and methods

Study design and participants

The sampling methodology of the NEHS has been described in detail elsewhere.[41] In brief, the target population was stratified into Indigenous Australians and non-Indigenous Australians. In accordance with Global Action Plan guidelines, the NEHS recruited non-Indigenous Australians aged 50 years or older.[3] However, as Indigenous Australians have earlier onset and more rapid progression of eye disease and diabetes,[42] a younger age of 40 years or older was selected. Based on the most reliable previous estimates of the prevalence of vision loss in Australia,[24, 43] the required sample size was 2794 non-Indigenous Australians and 1368 Indigenous Australians, residing in 30 geographic areas.

Multistage random-cluster sampling was used to select participants, based on data from the 2011 Australian Census.[44] In stage one of sampling, the Australian population was stratified into five remoteness strata: Major City, Inner Regional, Outer Regional, Remote, and Very Remote. Probability proportional to size sampling was used to select twelve Major City, six Inner Regional, six Outer Regional, four Remote and two Very Remote survey sites, corresponding to the approximate population distribution in each stratum. In the second stage a smaller cluster containing approximately 100 eligible residents was randomly selected and

nominated as the enumeration site. Due to a number of factors including insufficient population numbers, inaccurate Census data and high absentee rates, a systematic approach was used to make adjustments to some sites, including the use of backup sites and sampling from contiguous geographic areas. The details of this approach have been previously published.[41] Door-to-door recruitment was conducted until approximately 100 non-Indigenous participants were recruited from each cluster. Although door-to-door recruitment was used for the majority of participants, we consulted Aboriginal elders and local Aboriginal Health Services to ensure that our recruitment methods were culturally appropriate. In some instances, direct door-to-door recruitment was deemed culturally inappropriate, and telephone recruitment from formalised community lists was used as a substitute. Household recruitment, including door-to-door and telephone recruitment accounted for approximately 80% of Indigenous recruitment. Alternative methods of contact included concurrent Indigenous health clinics and word-of-mouth.

The protocol was approved by the Royal Victorian Eye and Ear Hospital Human Research Ethics Committee as well as State-based Indigenous ethics organisations. This study was conducted in accordance with the tenets of the Declaration of Helsinki.

Procedures

The examination protocol of the NEHS has been described in detail elsewhere.[45] Participant examinations were conducted in a total of 61 testing venues that included community centres, mobile clinics, town halls, Aboriginal Corporations, schools and medical clinics, all within 6 km of each recruitment site. Examinations were conducted over 13 months and 7 days, from March 11, 2015 to April 18, 2016. Residents attended testing centres at pre-specified appointment times and provided written informed consent. Standardised sociodemographic,

stroke, diabetes and ocular history data were collected using an interviewer-administered questionnaire.

Standardised eye examinations were conducted by researchers including ophthalmologists, optometrists, orthoptists, or research assistants trained at the Centre for Eye Research Australia (CERA). Presenting distance visual acuity was measured for each eye separately using a logMAR chart (Brien Holden Vision Institute, Australia) in well-lit room conditions. Pinhole testing was performed using a multiple pinhole occluder on participants with visual acuity <6/12 in one or both eyes. If visual acuity improved with pinhole testing, autorefraction was performed using a Nidek ARK-30 Type-R hand-held auto-refractor/keratometer (Nidek Co., LTD, Japan) and auto-refraction-corrected visual acuity was measured. Binocular presenting near vision was assessed using a CERA 'Tumbling E' near vision card (CERA, Australia) held at the participant's preferred reading distance. The smallest line at which the direction of at least 3 of the 4 'Tumbling E' optotypes was correctly identified was recorded. Visual fields were assessed using a Frequency Doubling Technology (FDT) perimeter (Zeiss Humphrey Systems & Welch Allyn, USA).

Examination of the anterior segment was performed using a hand-held slit lamp (Keeler Ophthalmic Instruments, UK) at 10x magnification. As *Chlamydia trachomatis* infection is endemic in Indigenous Australians, but not in non-Indigenous Australians, grading for trachomatous trichiasis and corneal opacity was performed in Indigenous participants only using the WHO Trachoma Simplified Grading System.[46] If presenting visual acuity was <6/12 in either eye, examiners took an anterior segment photo in the affected eye(s) with a Diabetic Retinopathy Screening (DRS)[47] camera (CenterVue, SpA, Italy).

Two-field, 45º colour fundus photographs were taken of each retina, centred on the macula and optic disc, respectively, using a non-mydriatic DRS camera in a darkened room to allow

for physiological mydriasis. In 663 cases (13.7%) where photograph quality was poor due to small pupil size, tropicamide 0.5% was instilled to induce mydriasis if anterior chambers were deemed wide enough to do so safely using the Van Herick method,[48] and photographs were repeated. Dilation was not performed where the angle was graded as 1 or 2. Intraocular pressure was measured using an iCare tonometer (iCare, Finland). Participants were provided with verbal feedback on the health of their eyes, and those with suspected pathology were provided with a referral letter to be taken to a local doctor or optometrist.

Blinded retinal graders at CERA graded all retinal images using OpenClinica software (OpenClinica LLC and collaborators, Waltham, MA, USA) and pathology was graded according to protocols that have been described in detail elsewhere.[47, 49, 50]

The main cause of vision loss was determined by two independent ophthalmologists and disagreements were adjudicated by a third ophthalmologist. Data pertaining to participants' age, gender and Indigenous status were provided to assist with disease attribution. Uncorrected refractive error was assigned as the main cause of vision loss when distance visual acuity improved to ≥6/12 in one or both eyes with pinhole or auto-refraction. For all other cases, ophthalmologists reviewed questionnaire responses and examination results to identify the condition most likely to account for vision loss. When multiple disorders were identified, the condition with the most clinically significant influence was determined to be the primary cause. For cases in which a single primary cause was not identifiable, vision loss was attributed to combined mechanisms. Cases of vision loss were deemed 'not determinable' if no cause of vision loss was identified.

Definitions

Vision impairment was defined as bilateral presenting distance visual acuity to ≥6/60.

Blindness was defined as bilateral presenting distance visual acuity <6/60.

Vision loss was defined as bilateral presenting distance visual acuity <6/12, and included all

cases of *vision impairment* and *blindness.*

Participants with presenting visual acuity <6/12 in one eye but ≥6/12 in the fellow eye (unilateral vision loss) were not considered to have vision loss for the purpose of this manuscript.

Statistical analysis

The crude prevalence of vision loss was calculated as the percentage of participants with vision loss. Prevalence was then weighted to account for the sampling rate in each remoteness stratum as population sizes varied between strata. This involved dividing the target population recruited from each stratum over the population size in each stratum. This also allowed the absolute number of Australians with vision loss in each stratum to be estimated. To facilitate comparisons between Indigenous and non-Indigenous Australians, the weighted prevalence of vision loss was adjusted for age and gender. Logistic regression analysis was used to identify risk factors for vision loss. Factors associated with vision loss at $p<0.10$ in univariable analysis were included in subsequent multivariable logistic regression analysis. A plot of the residuals compared with estimates was examined to test linearity and homoscedasticity. The Box-Tidwell model was used to find the best power for model fit based on maximal likelihood estimates. Logistic regression *Model 1* investigated risk factors for Indigenous and non-Indigenous participants together. In *Model 2* Indigenous and non-Indigenous participants were investigated separately. Analyses were conducted with Stata version 14.2.0 (Stata Corp, College Station, TX).

Results

Participant characteristics

Recruiters attempted to contact 23235 residences within the selected survey areas, of which 11883 (51.1%) were contactable. Of these, 6760 (56.9%) were deemed eligible to participate. In total, 3098 non-Indigenous Australians aged 50 to 98 years (mean [SD] = 66.6 [9.7] years)

and 1738 Indigenous Australians aged 40 to 92 years (mean [SD] = 55.0 [10.0] years) from 30 geographic areas were recruited and examined. Response rates, defined as the proportion of residents identified as eligible at the time of recruitment who participated in the survey, were 77.6% for Indigenous Australians and 68.5% for non-Indigenous Australians, with a combined response rate of 71.5%. Indigenous participants had fewer years of education ($p<0.001$), a higher prevalence of self-reported diabetes ($p<0.001$) and a higher prevalence of self-reported stroke ($p<0.001$) than their non-Indigenous counterparts (Table 1). Of all 4836 participants, 4692 (97%) had at least one gradable fundus photograph, with 67.5% (3265) having gradable images for both eyes. In total 59 (1.2%) participants had ungradable images in both eyes and 85 (1.8%) had missing images for both eyes.

The prevalence of vision loss

In total, 208 non-Indigenous participants had presenting visual acuity <6/12, resulting in a weighted prevalence of vision loss of 6.5% (95% CI 5.3-7.9). Extrapolating these findings to the entire target non-Indigenous Australian population of 6 544 763, approximately 400 000 non-Indigenous Australians aged 50 years and over were estimated to have vision loss (Table 2). Vision loss increased markedly with age in the non-Indigenous group, from 5.0% (3.6-7.0) in those aged 50-59 years to 37.3% (19.2-59.8) in those aged 90 years or older. Of those with vision loss, seven cases (0.21%, 0.06-0.73) were bilaterally blind (<6/60), corresponding to an estimated 12 636 Australians.

With 188 Indigenous participants found to have vision loss, the weighted prevalence in Indigenous Australians was 11.2% (9.5-13.1), corresponding to approximately 15 000 Indigenous Australians aged 40 years or over having vision loss. Bilateral blindness was present in five Indigenous participants, corresponding to a weighted prevalence of 0.31% (0.09-1.00) and a total number of 414 blind Indigenous Australians.

Following age and gender adjustment of the weighted prevalence of vision loss, the overall prevalence of vision loss in Australia, including both Indigenous and non-Indigenous Australians was 6.6% (5.4-7.8). Vision loss was 2.8 times more prevalent in Indigenous Australians than non-Indigenous Australians following age and gender adjustment(17.7%, 95% CI: 14.5-21.0 vs 6.4%, 95% CI: 5.2, 7.6, $p<0.001$). Vision loss was more prevalent in Indigenous Australians in all age groups, with those aged 60 to 69 years and 80 to 89 years having a greater than four times higher prevalence than age-matched non-Indigenous participants.

Risk factors for vision loss

Multivariable logistic regression *model 1* which included Indigenous and non-Indigenous participants in a single model, revealed that Indigenous status was associated with an odds ratio (OR) for vision loss of 2.4 (1.80-3.06) relative to non-Indigenous status ($p<0.001$). Due to this substantial difference, coupled with the different age inclusion criteria for Indigenous and non-Indigenous Australians, we created a stratified model in which risk factors were interrogated in Indigenous and non-Indigenous participants separately (*model 2*).

The results of *model 2* are presented in Table 3. In univariable logistic regression analysis, older age was a risk factor for vision loss in non-Indigenous Australians, with each decade of age being associated with an OR of 1.61 (1.35-1.93). Non-Indigenous participants who reported having not undergone an eye examination within the previous two years and those who had never had their eyes examined had a greater risk of having vision loss than those who had an exam within the past year. After adjusting for covariates in multivariable analysis, not having had an eye examination in the past year was shown to be a risk factor for vision loss in non-Indigenous Australians.

Vision loss was associated with most risk factors that were tested in univariable analysis in Indigenous Australians, including: older age, female gender, self-reported stroke, self-reported diabetes and geographic remoteness (Outer Regional and Very Remote residence, specifically) (Table 3). Educational attainment was inversely related to vision loss in Indigenous Australians. When adjusting for covariates, all variables identified as risk factors in univariable analysis remained strongly associated with vision loss apart from self-reported stroke and self-reported diabetes. As self-reported diabetes was shown to be a strong risk factor in univariable analysis (OR 2.06, 1.47-2.90), further investigation was conducted to identify its association with vision loss. We identified that the effect of diabetes was dependent on whether participants had previously undergone an eye examination. Self-reported diabetes was shown to not be a risk factor for vision loss in Indigenous Australians who had previously had an eye examination, while the OR for those with self-reported diabetes who had never undergone an eye examination was 14.47 (5.65-37.05). Whilst Very Remote residence was not strongly associated with vision loss in multivariable analysis (p=0.054), univariable analysis revealed an association (OR 2.05, 1.33-3.17, p=0.002), with the prevalence of vision loss being twice as high as in Major City, Inner Regional and Remote areas.

The causes of vision loss

The leading causes of bilateral vision loss in both Indigenous and non-Indigenous participants were uncorrected refractive error, accounting for 60.8% and 61.3% of cases, and cataract, accounting for 20.1% and 13.2% of cases, respectively (weighted proportions) (Figure 1). This was followed by age-related macular degeneration (AMD) in non-Indigenous participants (10.3%) and diabetic retinopathy in Indigenous Australians (5.2%). Vision loss was attributed to combined conditions for 2.9% of Indigenous Australians and 0.06% of non-

Indigenous Australians, while the main cause of vision loss was not determinable for 8.1% of Indigenous Australians and 8.7% on non-Indigenous Australians.

Of the five Indigenous participants with blindness, two cases were due to cataract, and the remaining three cases were attributed to diabetic retinopathy, optic atrophy and combined mechanisms, respectively. Five out of the seven blindness cases in the non-Indigenous cohort were caused by AMD, while one participant had optic atrophy and one case was not determinable due to poor retinal image quality

Discussion

This is the first nationwide study of the prevalence and causes of vision loss in Australia. We have shown that there is a disproportionately large burden of vision loss in Australia's Indigenous population, with a prevalence that is almost three times as high as non-Indigenous Australians. This, coupled with the identification of risk factors and the main causes of vision loss, provides the basis for targeted interventions to reduce the burden of vision loss.

Previously, the best estimate of the prevalence of vision loss in Australia's older population of 5.2% was derived from the pooled prevalence data from the Melbourne Visual Impairment Project (VIP) and the Blue Mountains Eye Study (BMES) conducted in 1992-1994.[43] These surveys were limited in their geographic coverage, selecting samples from the state of Victoria and a community near Sydney, respectively. The estimates of these studies were therefore representative of these populations, and could not be confidently extrapolated to the wider Australian population. Furthermore, temporal changes in parameters including population ageing and growth, and a higher prevalence of diabetes risk factors, have necessitated updated prevalence estimates. The prevalence of 6.5% reported in the current study is based on nationally-representative data and should be considered the most accurate estimate of the prevalence of vision loss in Australia's non-Indigenous population. Estimates

from this study will be useful for informing future national eye health policies and may function as the baseline to measure the progress of future interventions. Of particular relevance is the association between the increased risk of vision loss and older age in non-Indigenous participants, with the prevalence of vision loss more than tripling from ages 60-69 years to 80-89 years. Vision loss was also associated with not undergoing regular eye examinations reflecting a missed opportunity to identify and remediate leading causes of vision loss, such as uncorrected refractive error and cataract. These findings, considered in light of the fact that Australia's population is ageing rapidly, emphasise the need for individuals to undergo more regular eye examinations as they age, in order to ensure that the prevalence of vision loss does not increase in coming decades.

The weighted prevalence of vision loss of 11.2% for Indigenous Australians in the NEHS was slightly higher than that of the NIEHS (10.4%), however this may be due to the older mean age of our Indigenous cohort (55 vs 51 years). More importantly, the prevalence of vision loss was higher in Indigenous Australians compared to non-Indigenous Australians residing in all geographic remoteness strata and in all age groups measured in this study. This underlines systematic insufficiencies in the delivery of required eye care services to Indigenous communities.[51] The gap in Indigenous eye health has been well-established, and the Roadmap to Close the Gap for Vision provides a framework for the improvement of eye care services.[52, 53] This survey identified numerous risk factors for vision loss in Indigenous Australians. The finding that the prevalence of vision loss in Indigenous women was 1.4 times higher than in Indigenous men highlights the need for further investigation into this gender disparity and an urgent need to provide equitable eye health care to all Indigenous Australians.

The finding that uncorrected refractive error and cataract, both reversible, were the main causes of vision loss in both Indigenous (81%) and non-Indigenous (75%) participants is

reflected in previous Australian research.[24, 38, 54, 55] These conditions remain the leading causes of vision loss for a multitude of reasons that are likely to differ between Indigenous and non-Indigenous Australians and across different regions in Australia. For example, the prohibitive distances to spectacle-dispensing services and cataract surgery facilities, coupled with the lack of outreach services has resulted in insufficient and inequitable treatment coverage for both conditions.[56] Furthermore, the continually-increasing incidence of cataract[57] and long cataract surgery waiting times[58] may be further hindering efforts to reduce disease burden, while sub-optimal coordination of spectacle-dispensing services, cost-uncertainty and affordability particularly for Indigenous Australians,[51] may contribute to inadequate treatment of refractive error. Perhaps most importantly, insufficient eye examination frequency in older Australians may result in a lack of detection and correction of refractive error. Consequently, by implementing a well-coordinated nationwide needs-based strategy that addresses these deficits while increasing eye health promotion to improve service utilisation, Australia would successfully supersede its commitment to the Global Action Plan.

Diabetic retinopathy contributed to 5.2% of vision loss in Indigenous participants, but less than 1.5% of vision loss in non-Indigenous participants. This reflects the substantially higher prevalence of self-reported diabetes in Indigenous participants (37.1% vs 13.9%) and the higher prevalence of advanced vision-threatening diabetic retinopathy in Indigenous Australians that has been attributed to insufficient use of early detection and treatment services.[59] Implementing strategies to target risk factors for diabetic retinopathy, including glycaemic, lipid and blood pressure control in Indigenous communities, while also enhancing screening services [supported by the strong association with vision loss in those who had diabetes and had never had an eye examination (OR 14.47)] may contribute to reducing the burden of vision loss in Indigenous Australians.[52]

As the leading cause of blindness (71%) and one of the leading causes of vision impairment in Australia and other high income countries, the burden of AMD as a public health concern is likely to increase with the ageing of the population.[60] As the vision loss induced by AMD is largely irreversible, early detection, treatment and education on prevention is critical in slowing disease progression.

Many national eye health surveys have utilised Rapid Assessment of Avoidable Blindness (RAAB), Rapid Assessment of Cataract Surgical Services (RACSS) or similar methodologies.[61, 62] The strengths of these study designs are their relative inexpensiveness and that they utilise multistage sampling frames, while permitting rapid identification of obvious ocular disease. However, their practical utility is hindered by a number of weaknesses, including simplified ophthalmic examinations (often consisting of only slit lamp and ophthalmoscopy thereby limiting disease attribution) and rigid non-stratified sampling methods that do not account for heterogeneous populations.

Population-based eye surveys that have implemented some level of stratification, however crude, have consistently revealed geographic[14, 15, 18] or ethnic[34, 63, 64] variations. Therefore, it is likely that non-stratified surveys may not adequately identify regions and ethnic groups most in need of improvements in eye health care services. Through our stratified sampling methodology, in which we have collected large samples of both Indigenous and non-Indigenous participants from all levels of geographic remoteness, we have shown that the Indigenous people of Australia, particularly those living in non-metropolitan areas, have a substantially higher risk for vision loss. These findings will strengthen national programmes aiming to reduce the burden of vision loss by assisting policy-makers and health providers to allocate limited resources to communities most in need.[52] Based on our findings, future population-based surveys may benefit from using similar stratification methods to identify and investigate Indigenous groups in countries with defined Indigenous populations.

A limitation of this study resulted from Australia's unique geographic and population structures, including its unusually low population density.[65] A systematic protocol was used to reduce the risk of bias when selecting new population clusters imposed by prohibitively low population densities, high absentee rates and erroneous census data. Nonetheless, the complete elimination of both non-response bias and selection bias could not be achieved as non-responders and absentees may have differed from responders in ways relevant to study outcomes. An additional limitation is that the sample size was calculated to detect the prevalence of vision loss in general, and the study was not powered to achieve precision in the estimates of the causes of vision loss, the prevalence of vision loss by age, or the presumably much lower prevalence of blindness. Future studies may benefit from having larger samples, but the benefit must be weighed against the financial and logistical consequences

In light of the aim to reduce the prevalence of avoidable vision loss by 25% before the year 2020 under the Global Action Plan, there is an urgent need for more countries to conduct well-designed national eye health surveys to identify at-risk populations to guide domestic strategies in the fight against vision loss. In Australia, uncorrected refractive error and cataract, both reversible, remain the leading causes of vision loss, highlighting that avoidable vision loss can be largely addressed by implementing needs-based nationwide strategies that improve rates of spectacle correction and cataract surgery. Diabetic retinopathy and AMD contribute significantly to the burden of vision loss in Australia, and early detection and treatment are well known to reduce the burden of vision loss from these conditions. Indigenous Australians have a high burden of vision loss, and properly stratified surveys in other countries with Indigenous inhabitants, or indeed other marginalised population sub-groups, may reflect these findings in those populations, thereby informing targeted interventions to reduce vision loss in those countries.

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Figure 1. The weighted main causes of vision loss (presenting bilateral distance visual acuity <6/12) in Indigenous and non-Indigenous participants
Values are the proportion [% (95% confidence interval)] of vision loss attributed to each main cause. Values are adjusted for sampling weights.
'Refractive error' is uncorrected or under-corrected refractive error. Combined Mechanisms were assigned if there were two or more causes of vision loss.
Other causes of vision loss included retinal dystrophy, optic atrophy, retinochoroidal scarring, retinitis pigmentosa, myopic retinochoroidal degeneration, keratoconus.